3.6 REFRIGERATION

THE CARRIER CENTRIFUGAL REFRIGERATING MACHINE

The vapour-compression refrigeration cycle is used in the centrifugal compressor system which is typically provided as a packaged water chilling unit, complete with evaporator and condenser. Compression is accomplished through centrifugal force, and since this is not positive, only a low pressure differential is developed, requiring a refrigerant having the characteristics of high molecular weight and low vapour pressure [BSE, 256-7].

Although Willis Carrier developed the first practical water-chilling centrifugal machine in 1921, others before him had tried, but without success. In particular, the Frenchman Maurice Leblanc obtained a broad patent in 1913 and built an experimental machine, using water vapour as the refrigerant. However, its low molecular weight meant he was unable to design an impeller of sufficient mechanical strength for the necessary high rotating speeds. Willis Carrier took up the challenge when he recognised the need for a water-chiller to serve the potential comfort air conditioning market. At this time most systems of mechanical cooling used direct-expansion of the refrigerant, suitable for industrial applications, but the hazardous refrigerants then in use (ammonia, methyl chloride and sulphur dioxide were toxic, carbon dioxide required high pressures) were unsuitable for in crowded areas. Around 1920, Willis Carrier returned to the problem. The story of how he went to Germany and found both a suitable refrigerant and a manufacturer capable of building a prototype has been told elsewhere [15/459, 900, 903 & other references listed].

Willis Carrier publicly demonstrated his first centrifugal refrigerating machine at the Company's offices in Newark in 1922, before a gathering of prominent ASRE members. [This used a 4-stage compressor with dichlorethane as the refrigerant and provided a capacity of 70 TR.] In 1923, the first 3 machines were sold to Whitman & Sons, a candy manufacturer in Philadelphia. The second order came from Schrafft & Sons of Boston. By the end of 1924, nine machines had been sold, including the first experimental model which went to the Onondaga Pottery Company of Syracuse, where it operated until around 1960, being placed in the Smithsonian Institution in 1962 [15/748]. The first comfort air conditioning application of the machine was for the J L Hudson Department Store in Philadelphia in 1924, when 3 machines each of 195 TR were provided. An opening into the relatively new comfort market came when centrifugal chillers were introduced into motion-picture theatres: The Palace, Dallas; the Iris & Houston, Houston; all in 1924. However, the installation (2 machines, each of 210 TR) that was to later open up the market for CEC in the UK was for the Rivoli, New York in 1925, when the opening night was attended by Adolph Zukor, head of Paramount [FAC, chap.IX].

The CEC documents say little about the introduction of the Carrier centrifugal into the UK, but its availability, coupled with the wealth of air conditioning knowledge, built up by the then US parent company, gave CEC a superb entry into the UK air conditioning market. Machines were imported from the USA. The first installation was in 1926 for the Daily Mail in London, followed by installations for the textile, confectionery and tobacco industries [Appendix-D]. Often repeat orders followed.

Carrier Centrifugal Refrigeration

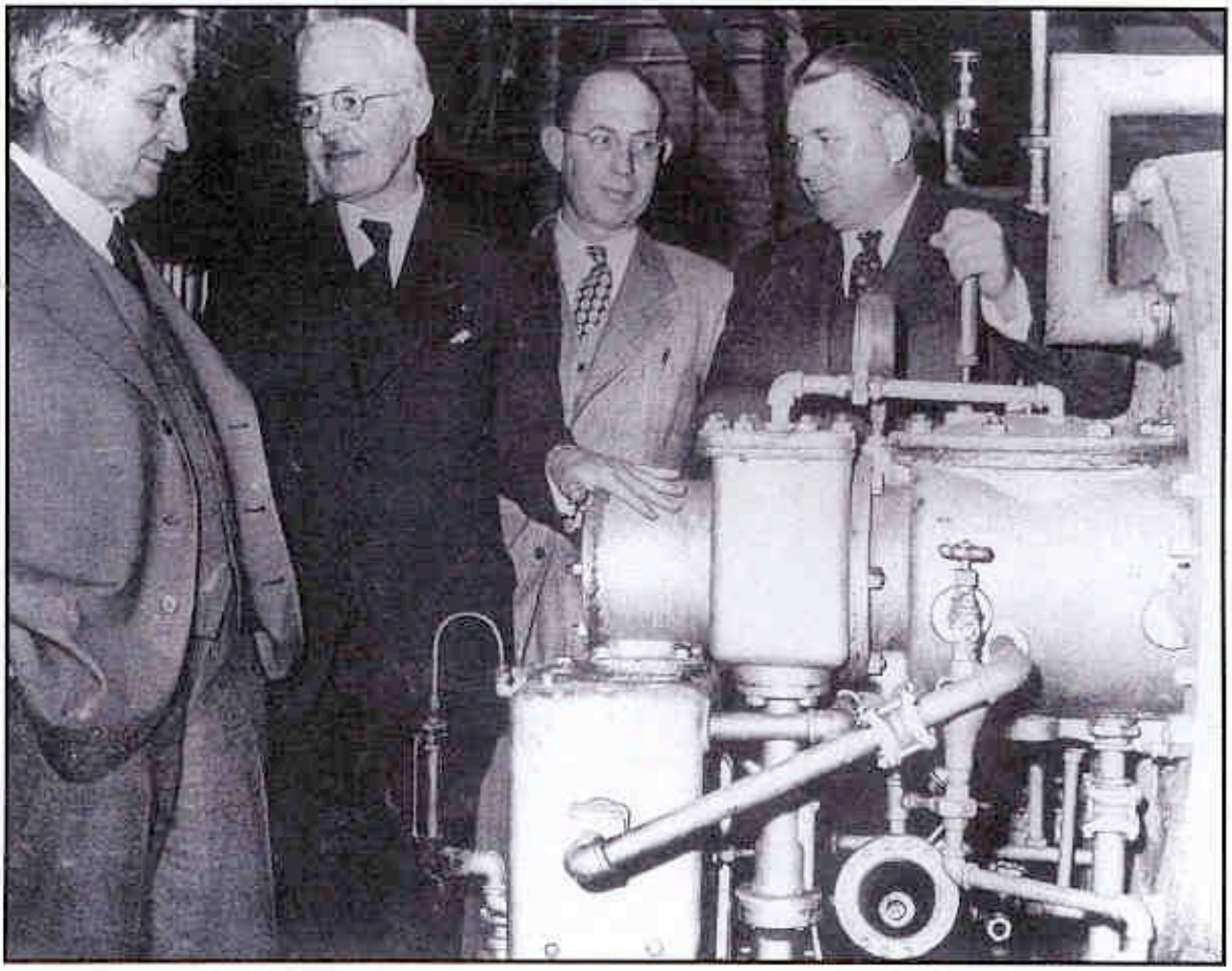
Carrier Engineering Company Ltd
24 Buckingham Gate, London.

CEC catalogue on Centrifugal Refrigeration. 1930s [6/326, title page].

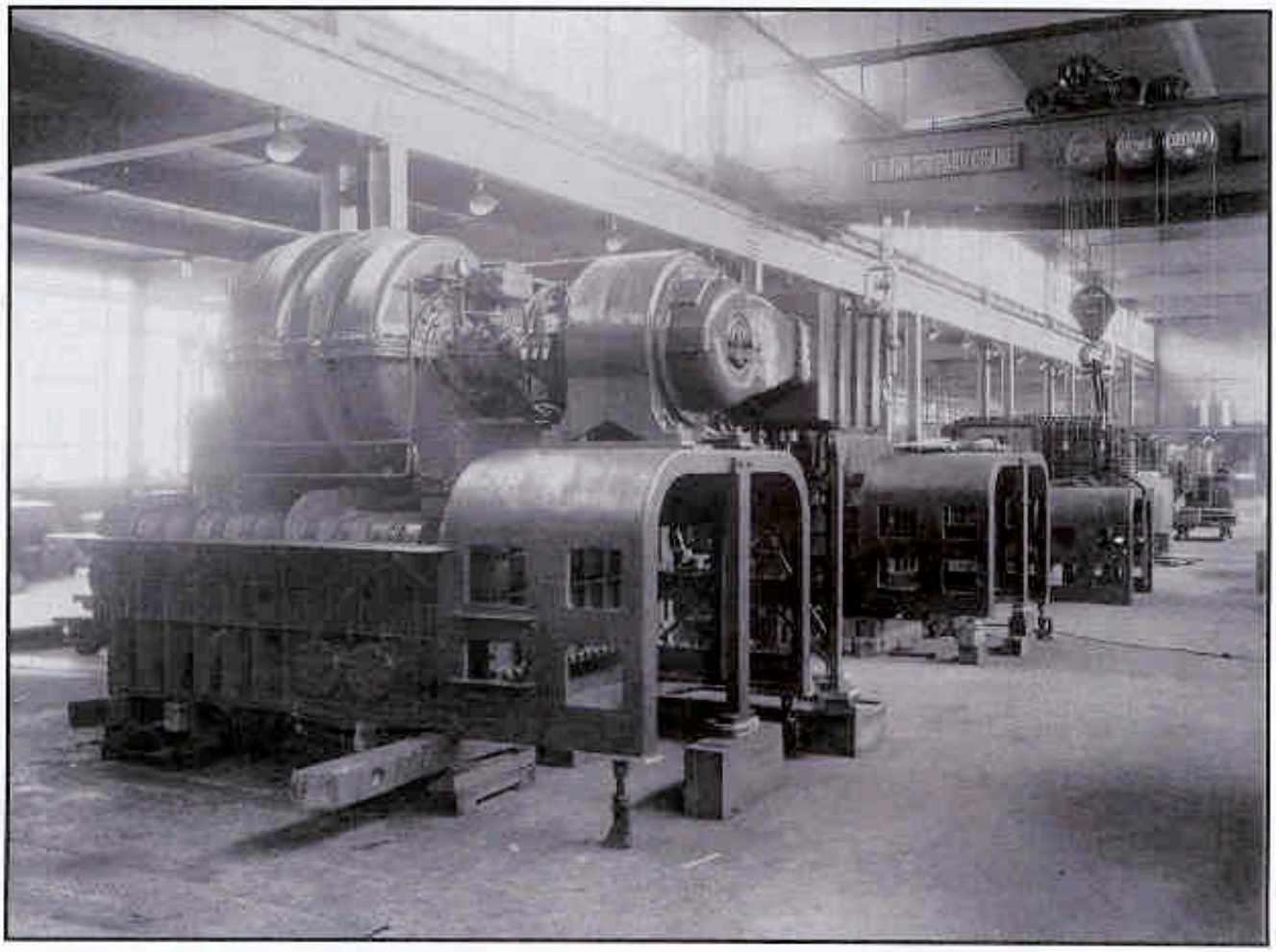
The entry into cinema air conditioning came with the first fully air conditioned installation for the Carlton Theatre in London's Haymarket in 1927 which was the 4th centrifugal to be provided in the UK [5/553]. In 1928, CEC air conditioned the new Empire Theatre in Leicester Square using a 250 TR machine. In 1929, CEC followed this with a 150 TR centrifugal for the Paramount Theatre in Paris. [15/326]. Other Paramount theatres followed, no doubt influenced by the successful installation at New York's Rivoli. Centrifugals were provided for the Paramounts at Manchester, Leeds [5/553] and it is believed for those in Liverpool, Manchester and in the Tottenham Court Road. In many other cinemas, which CEC list as air conditioned [6/502], including a number of architecturally-renowned Astorias, no evidence has been found that these were other than spray washer systems without refrigeration.

Three notable installations of the centrifugal water chiller were for the BBC building at Portland Place in 1931, for the Cumberland Hotel at Marble Arch about 1932, and for Princes House in Gresham Street, around the same time. The installation at the Cumberland employed 2 machines, one driven by an electric motor, the other by a steam turbine, with a total capacity of 500 TR. The BBC had a single machine of 200 TR; the capacity of the Princes House machine is unknown.

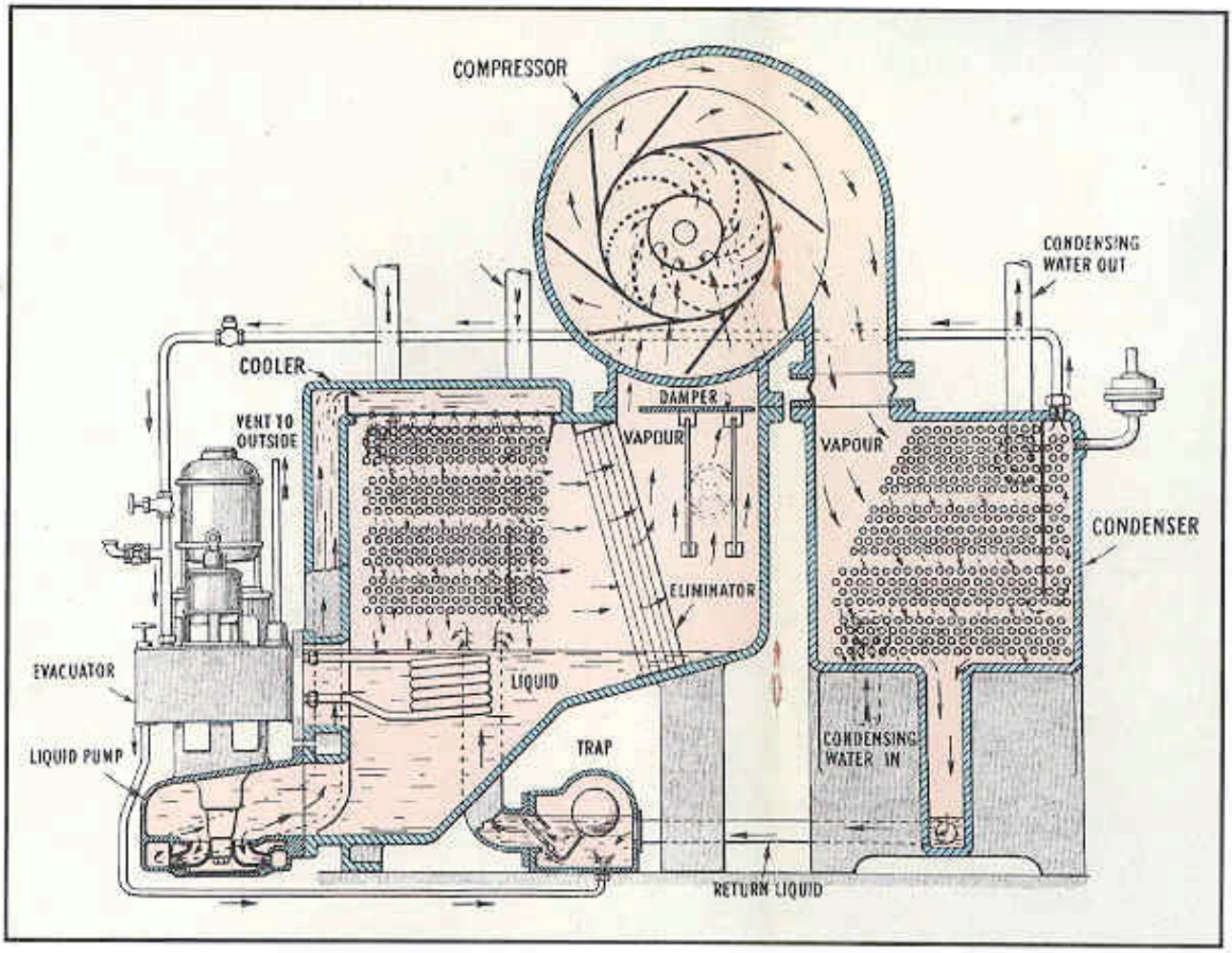
At some point in time, CEC imported only the compressors and arranged for UK manufacture of the condensers and evaporators. Immediately after World War II, restrictions on dollar imports, led CEC to manufacture absorption machines at their Wembley factory, as an alternative to the centrifugal.



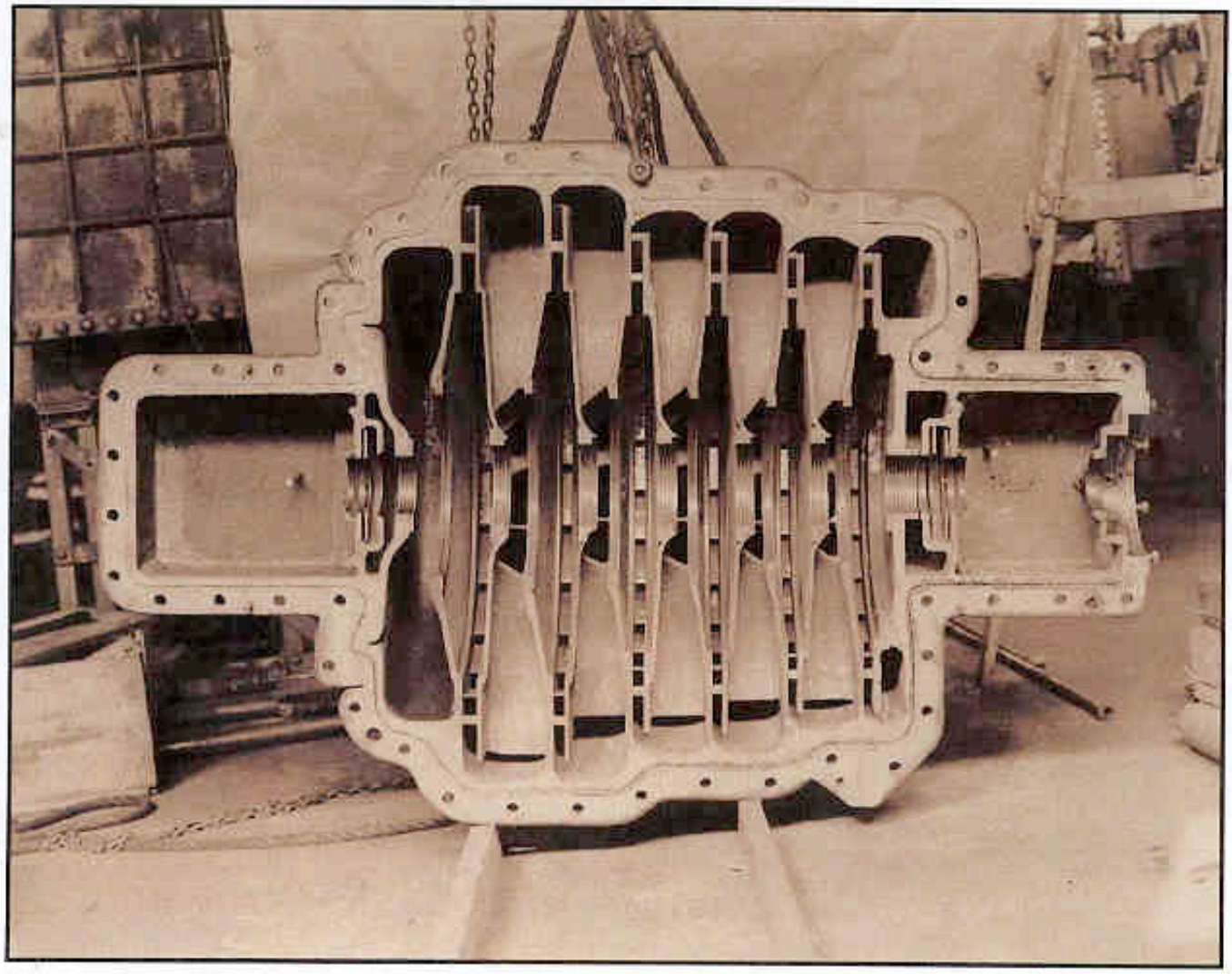
Willis Carrier (left) with the first centrifugal chiller, c.1950 [CHG].
Installed in the Onandaga Pottery Company, Syracuse in 1922.



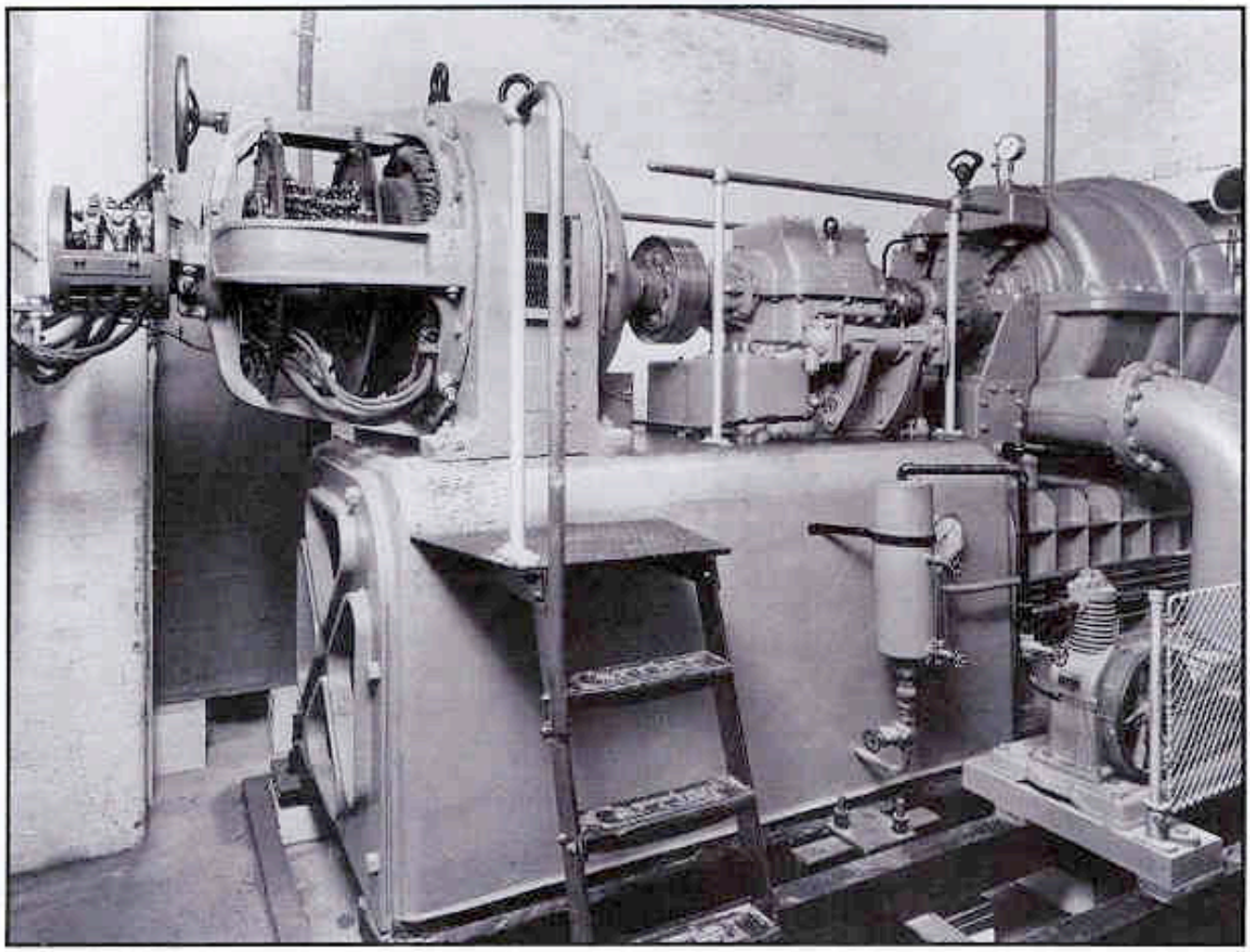
Centrifugal refrigeration production line, 1920s [P-589].
Carrier Engineering Corporation, Newark, New Jersey.



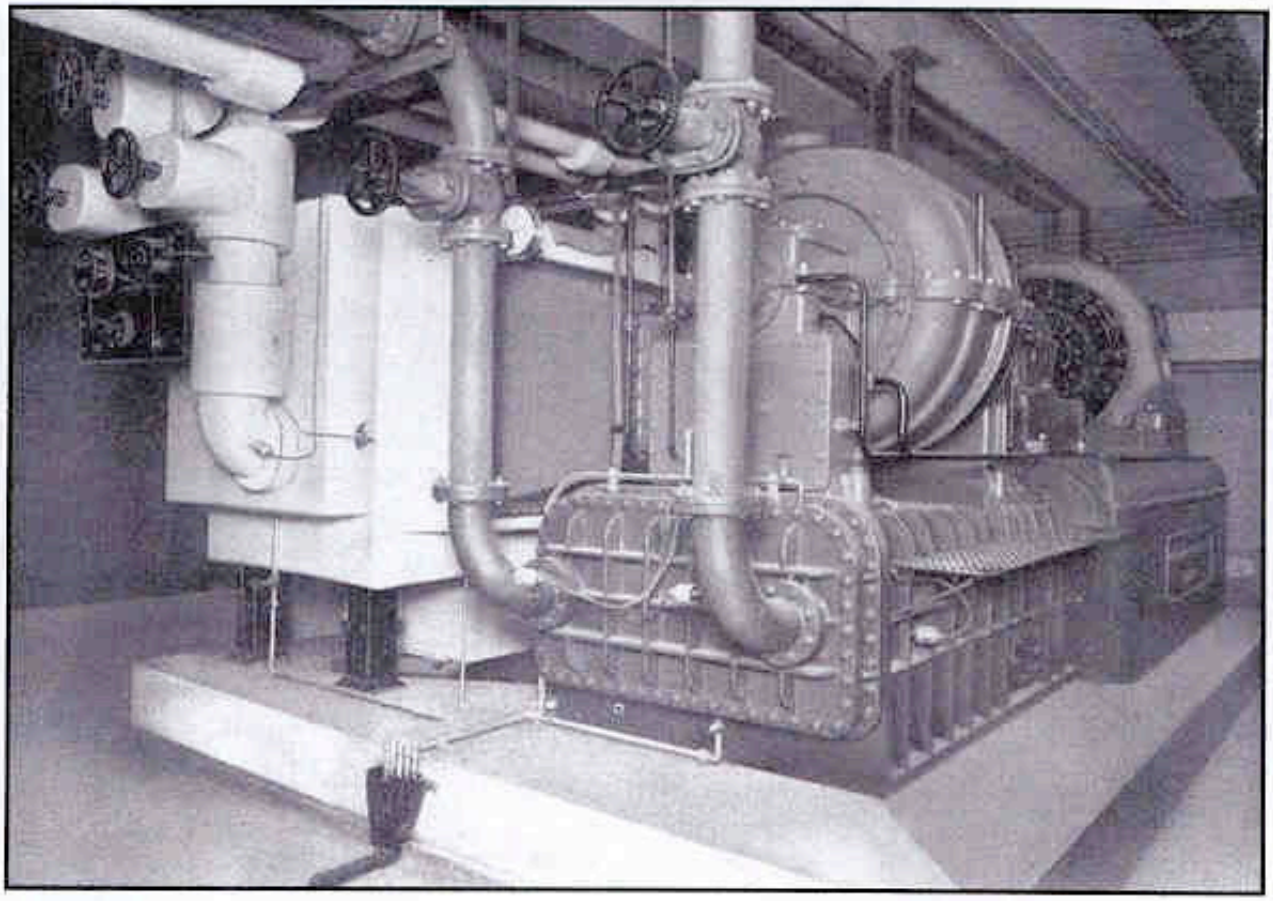
Cut-away drawing of the Carrier centrifugal refrigerating machine [15/326, 8-9].



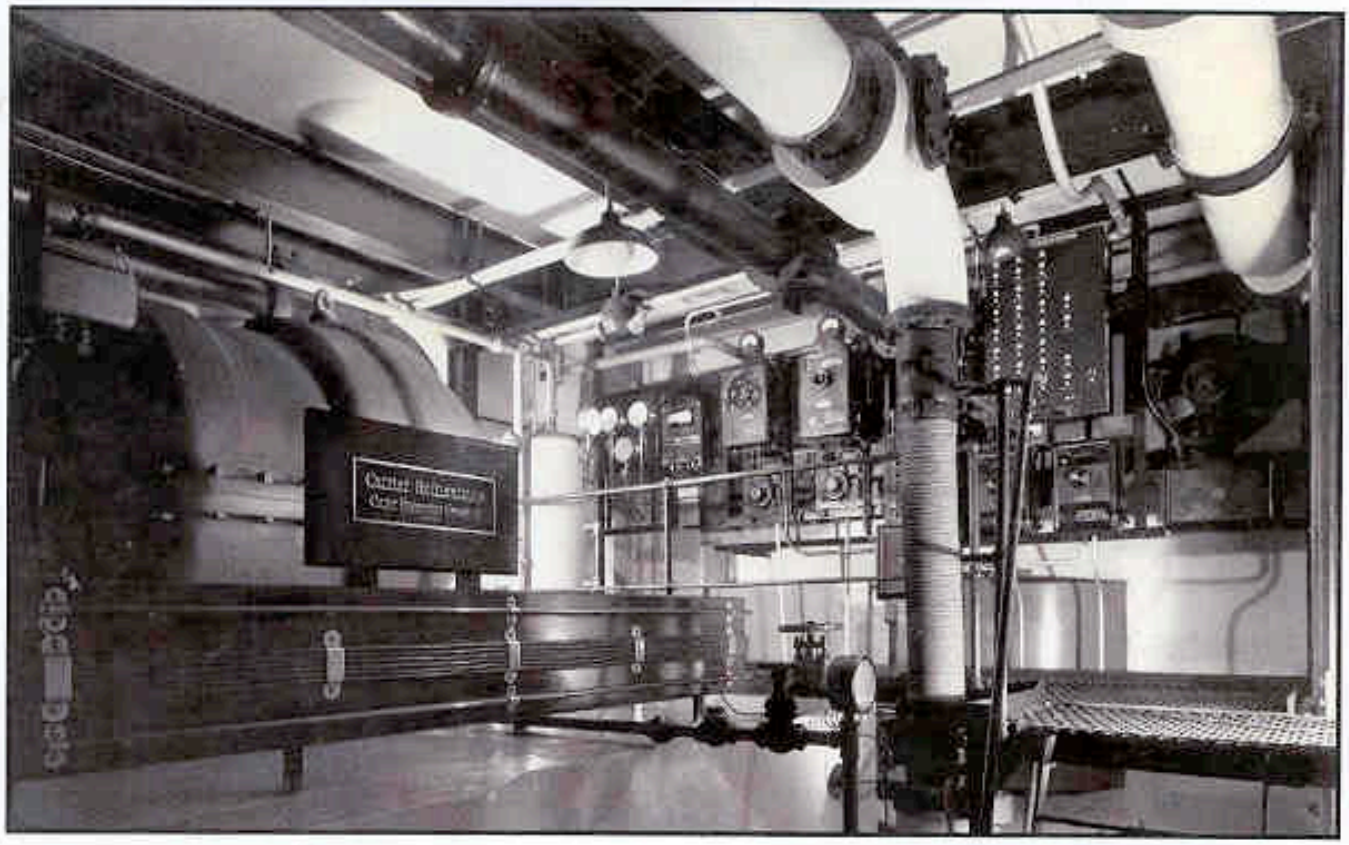
Internal of Carrier centrifugal compressor showing muti-stage impeller [P-593].



Carrier centrifugal chiller at the Carlton Theatre, Haymarket, London, 1927 [P-600].



Carrier centrifugal chiller of 250 TR at the Empire, Leicester Square, London, 1928. [15/326, 10].



Carrier centrifugal chiller, Princes House, Gresham Street, London, mid-1930s [CHG 7-4].

THE CARRIER ABSORPTION REFRIGERATING MACHINE

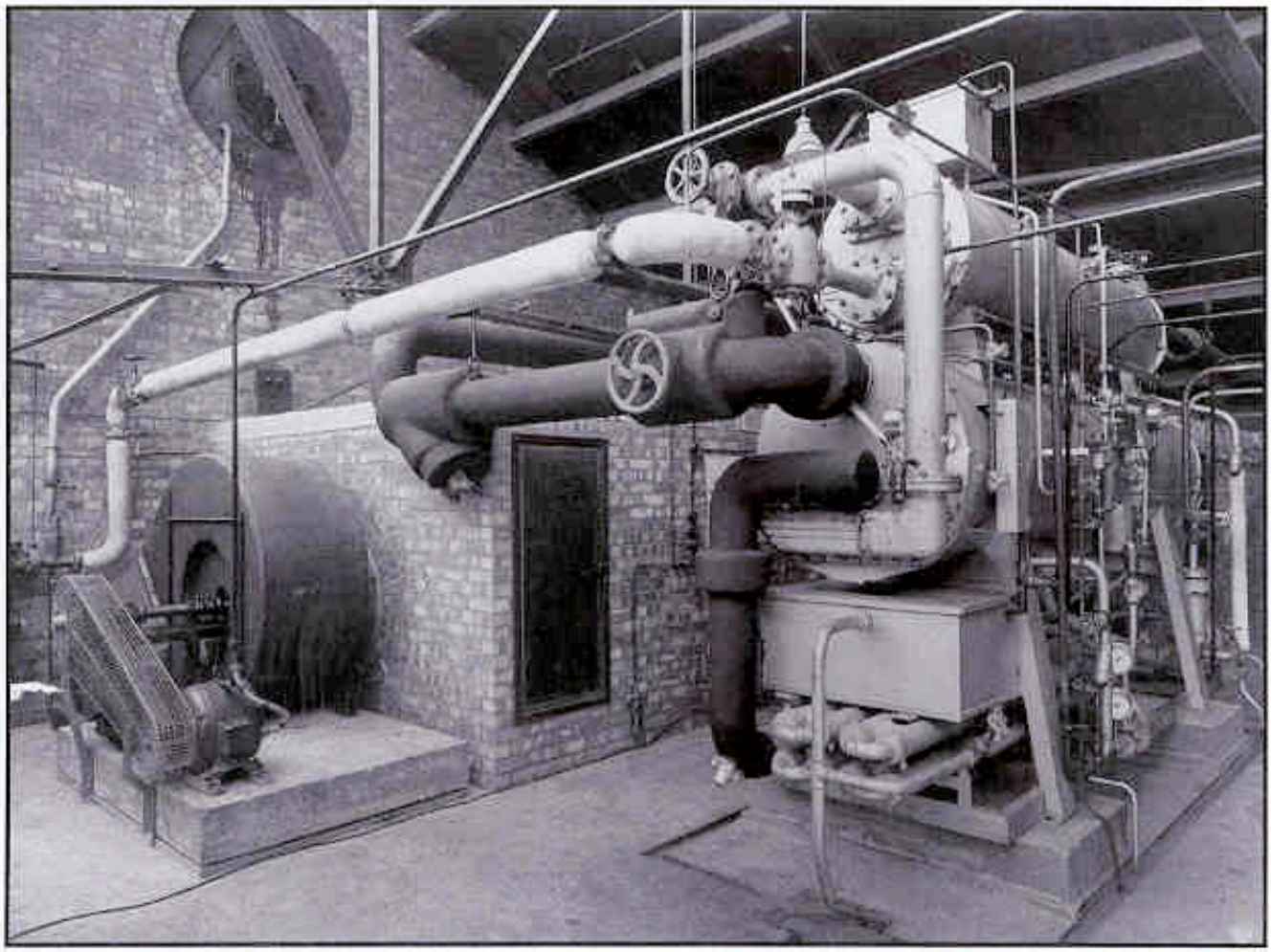
The absorption refrigeration machine is heat operated. It uses an absorption solution (absorbent plus refrigerant) that can absorb refrigerant vapour, and a refrigerant which boils (flash cools itself) when subjected to a lower pressure. Since the 1950s the absorbent is commonly lithium bromide and the refrigerant is water. Water is sprayed into an evaporator maintained at a high vacuum, so that a portion of the water flashes into vapour and cools the remainder. The vapour is then absorbed by the lithium bromide solution in the absorber, and the resulting solution is heated in a generator to drive off the moisture. This is liquefied in the condenser before returning to the evaporator to repeat the cycle [AVB, 225-6].

The absorption refrigerating machine was introduced by the Frenchman Ferdinand Carré in 1857. He perfected a very small intermittent aqua-ammonia system in 1859 and the same year developed a continuous machine for commercial use. The latter was first manufactured in Paris in 1860 by Mignon & Rouart, but its main commercial success was achieved in the southern states of America during the Civil War. Using steam as a source of heat, in an age of steam, it was considered by many to be superior to the early steam-engine driven compressor refrigeration systems of the day. Its use faded with the introduction of the electric motor. [BSE, 258-63: HAC, 127-130: HR, 45-6].

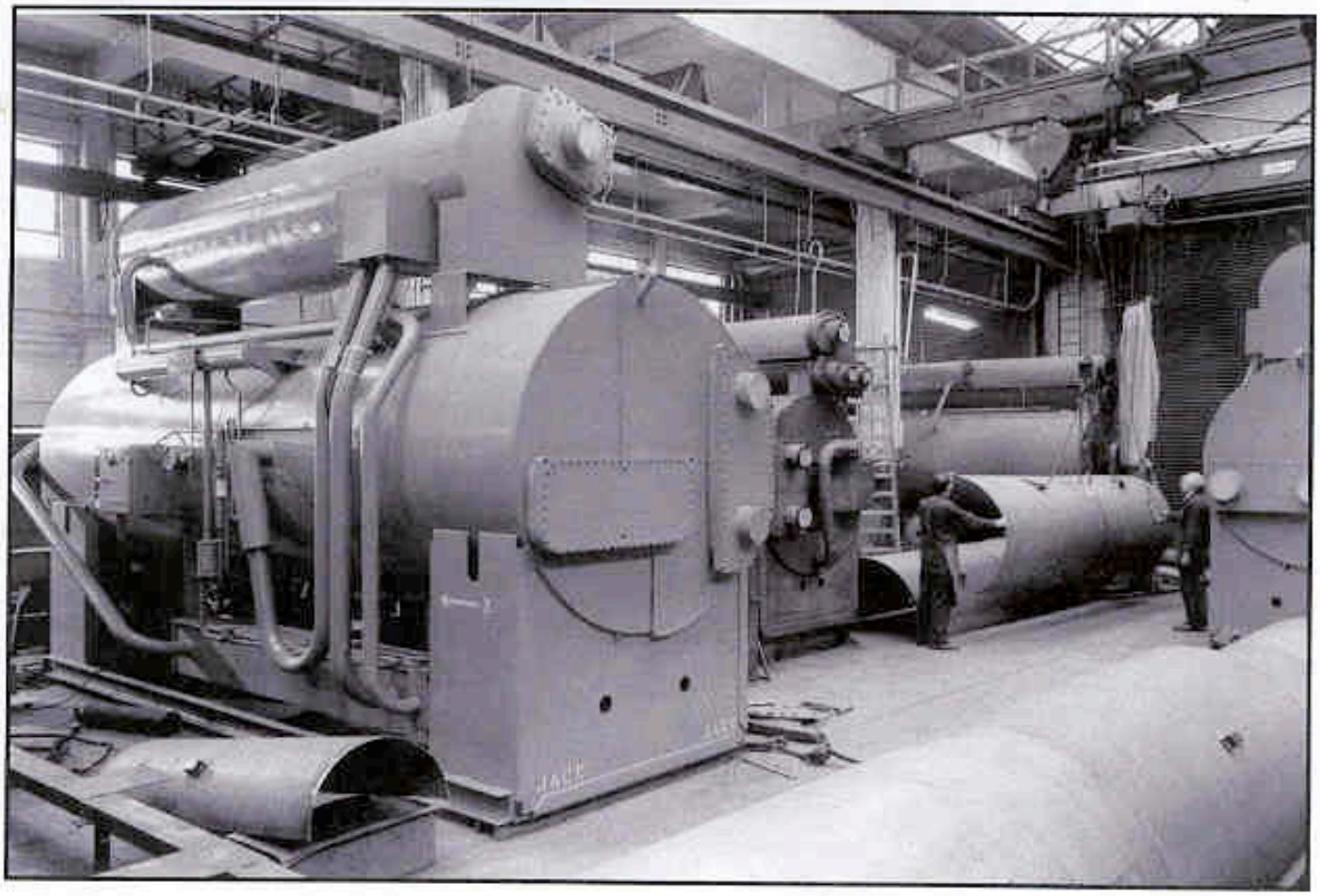
The possibilities of absorption refrigeration were again realised in the USA. During Word War II, A A Berestneff of Carrier Corporation headed an extensive research programme to develop a machine for water-chilling service to compete with modern compression machinery. By the end of the War, such a machine was commercially available [16/641].

Early in 1946, CEC had grave concerns with regard to the development of their air conditioning business, principally because of difficulties in sourcing suitable refrigerating machines. Before the War, CEC had imported Carrier centrifugal compressors from the USA and arranged manufacture of the condenser and evaporator in the UK. Now, there was a disadvantage with the dollar requirement for the import of the compressor. A possible solution seemed to be the manufacture of the compressor in the UK, but an investigation of past and possible future business showed the market to be too small, and the type and size of compressor too diverse, to set up an economic production line. Following a visit to the USA in 1946, CEC decided to manufacture the new absorption machine in the UK. Their factory was capable; there was no dollar problem [16/640].

The original 1946 design was for a 150 TR lithium bromide machine [16/643]. This design was of the "open" type, requiring all connections between it and the chilling surface to be vacuum type, precluding its use with either spray type dehumidifiers (air washers) or with lengthy chilled water piping circuits. Using an intermediate chilled water/chilled water heat exchanger was not an attractive answer. CEC nearly completed an early sale for 4 machines to Imperial Tobacco, Bristol to supply chilled water for existing spray dehumidifiers without, apparently, recognising these limitations. Fortunately, for all concerned, the sale was not realised.



The 150 TR experimental absorption machine at J Lyons, Greenford, 1952 [14/628].



Manufacture of Type JA absorption machines at CEC Wembley, c.1972 [14/632].

An early experiment was carried out with the co-operation of Mars Ltd at their factory to test the CEC claim of the machine producing chilled water at 40° F. It was said "the claim was substantiated but not on a real working basis and the machine was eventually removed." Fortunately, by the generosity of J Lyons & Company, 2 machines were installed at Greenford with facilities to monitor steam and electricity consumption, and these tests proved highly satisfactory [16/633].

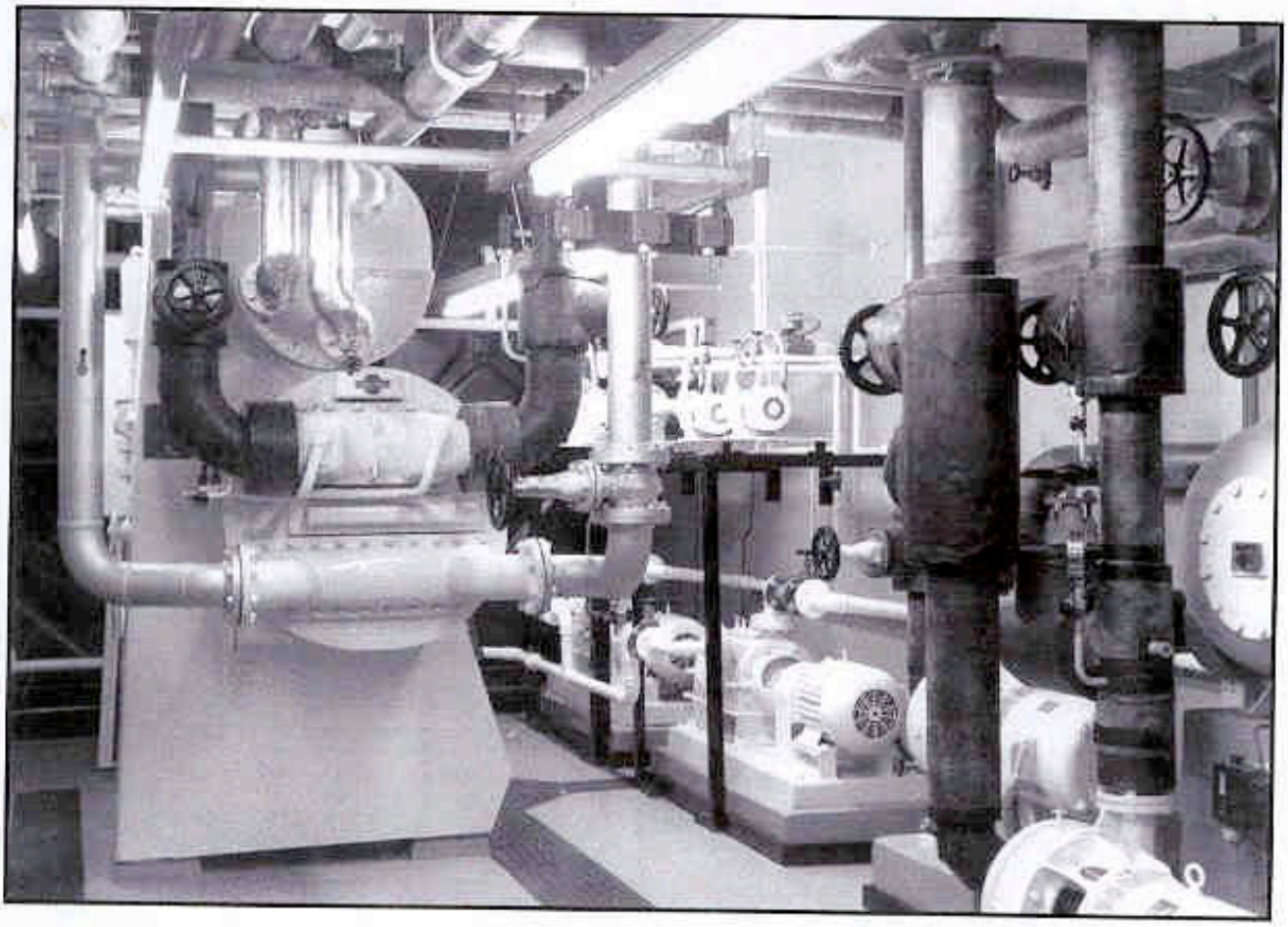
At the CEC factory in Wembley, where these first 16B series machines were produced, there were considerable problems in post-war UK to obtain materials and implement production methods to meet US standards. Eventually, by 1949, the first 16B5 was installed in the BBC TV Studio at Lime Grove [and went on to provide satisfactory operation for 27 years, when it was removed for having insufficient capacity to meet new demands]. Its success was followed during the next five years by the manufacture of a further 22 machines for a wide variety of clients, many of them Middle-East oil companies [Appendix-E].

During this period the limitations of the open type machine forced Carrier Corporation to design a closed machine with an integral chilled water circuit, thus avoiding external vacuum-tight connections. The new 16C machine dispensed with the previous 2-stage steam and water purge, replacing this arrangement with a lithium bromide solution purge. At the same time, costs were reduced by doing away with a considerable quantity of stainless steel. A total of 34 of the 16C type machines, now up to 500 TR capacity, were manufactured and installed by CEC up to 1963, including 6 machines for the BBC for air conditioning work [Appendix-E].

Competing sales and production requirements produced many a fierce argument, none more heated than when in order to produce the largest machines, it was found necessary to raise the height of the Wembley factory roof at a cost of £70,000. Visiting clients also produced heart-stopping moments. When M T Tudsbury of the BBC inspected the absorption machine test-rig he enquired (tongue-in-cheek it is hoped) whether the factory of Lightfoot Refrigeration opposite was pumping chilled water to CEC through underground pipes [16/633].

The 16E machine was developed in 1962 but very few were produced either in the UK or USA. The next major change was the 16H, an hermetic machine, up to 1000 TR capacity, and tested at CEC Wembley by mass spectrometer. From 1963 to 1971, 36 machines of the 16HA type were manufactured and installed. From 1971 to 1976, CEC sold 26 machines of the JA type and 63 machines of the JB type. Absorption equipment was now being purchased by CEC competitors in the contracting field: G N Haden, Andrews-Weatherfoil, Norris Warming, with perhaps the largest order being from Drake & Scull -six machines with a total capacity of 3000 TR for Hallamshire Hospital in Sheffield [Appendix-E].

However, during this period, the dollar exchange problem disappeared, and the rising costs of UK production, now considerably higher than in the USA, led to the end of UK production by CEC. Absorption machines for use in the UK and Europe were henceforth to be imported from Carrier Corporation in the USA.



Type 16E113 absorption machines at CEC, Carrier House, London, 1963 [14/637].